2004 COMMITTEE OF VISITORS REPORT FOR THE BIOCOMPLEXITY IN THE ENVIRONMENT COMPETITION (2001-2003)

February 25-27, 2004

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Date of COV: **February 25-27, 2004**

Program/Cluster: **Biocomplexity in the Environment Competition**

Directorates:
Geosciences
Biological Sciences
Computer and Information Sciences and Engineering
Education and Human Resources
Engineering
Mathematical and Physical Sciences
Social, Behavioral, and Economic Sciences
Office of International Science and Engineering
Office of Polar Programs

Number of actions reviewed by COV: 150 Awards: 75 Declinations: 75
Total number of actions within Program/Cluster/Division during period being reviewed by COV: 850 Awards: 143 Declinations: 707
Manner in which reviewed actions were selected: See description in Section 2.0 COV Process

Committee Membership:

Elizabeth J. Kelly (Co-Chair), Statistical Sciences, Los Alamos National Laboratory, Los Alamos, New Mexico
Mary Jane Perry (Co-Chair), University of Maine's Ira C. Darling Marine Center, Walpole, Maine
Peter D. Blair, Division on Engineering & Physical Sciences, National Academy of Sciences, Washington, D.C.
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1.0 OVERVIEW OF FINDINGS AND RECOMMENDATIONS

The Committee of Visitors (COV) for the National Science Foundation's (NSF) Biocomplexity in the Environment (BE) competition met in Washington, DC, on February 25-27 to review the BE research program. BE is a cross discipline activity involving seven directorates and two offices (Geosciences; Biological Sciences; Computer and Information Science and Engineering; Education and Human Resources; Engineering; Mathematical and Physical Sciences; Social, Behavioral, and Economic Sciences; Office of International Science and Engineering; and Office of Polar Programs). The BE competition consists of five topical areas: 1. Dynamics of Coupled Natural and Human Systems (CNH); 2. Coupled Biogeochemical Cycles (CBC); 3. Genome-Enabled Environmental Science and Engineering (GEN-EN); 4. Instrumentation Development for Environmental Activities (IDEA); 5. Materials Use: Science, Engineering, & Society (MUSES).

The COV was charged to evaluate the "integrity and efficiency of the program's processes and management" and to assess the "outcomes and outputs" in terms of NSF's strategic areas of "people, ideas, and tools." The COV reviewed material related to the BE competition for all five topical areas for solicitations for the 2001-2003 time period (NSF 01-34, 02-010, 02-67). The COV developed consensus findings and recommendations for the BE competition as a whole. The COV did not evaluate proposals or programs outside of the competition, e.g., activities supported by the "unfenced" BE priority area funds. The COV, as the first to evaluate a multidisciplinary, cross-cutting, NSF-wide activity on the scale of BE, also was asked to provide comments on the COV process itself, particularly with respect to applying the COV template to a multi-disciplinary priority area. The following discussion summarizes the BE COV's findings and recommendations; more specifics are covered in the responses to Questions A, B, and C in the COV template.

Outcomes and Outputs. A key finding of the COV is that the NSF through the BE competition has fostered an important new area of multidisciplinary research addressing challenging environmental questions, including the explicit role of humans. The BE program components are responsive to needs of the research and education communities, decision-makers and the general public. Although there was initial confusion as to the exact definition of biocomplexity when the competition was first introduced in the FY99 solicitation, BE has evolved into truly a cross-cutting competition with five topical areas covering a broad range of multidisciplinary research.

A large part of the extraordinary success of the BE program is a result of the leadership and dedication of the NSF staff, who not only nurtured the fledgling program while conducting a high quality and rigorous evaluation of proposals, but who also maintained exceptional excitement and enthusiasm for BE research objectives.

There has been an impressive response from the community as demonstrated by the development of new multidisciplinary communities, the realignment of departments and resources in universities, the establishment of new centers, the creation of a new journal dedicated to biocomplexity, the establishment a new Gordon Conference series in biocomplexity, and the inclusion of workshops and special sessions on BE at professional society meetings. These responses demonstrate that NSF has

met a need in the community for multidisciplinary research and education to address environmental challenges. The explicit requirement for integration of research and education in the request for proposals has resulted in strong educational and outreach activities in the BE proposals. Examples of outcomes from awards include new undergraduate courses, professional development programs for teachers, inclusion of minority groups in research experiences, and outreach to the general public.

BE, particularly CNH, is to be commended for its efforts to incorporate the social sciences into the program and its competitions. The program's emphasis on interactions and impacts of human factors in the global ecological system has ensured the early inclusion of social sciences in this new area of research. The COV believes this may contribute to more mutual partnerships between the social and natural sciences than commonly occurs. Although the multidisciplinary community is growing, collaborations between social scientists and natural scientists and engineers have not yet achieved the levels hoped for by members of the COV and some NSF staff. The following observations are made with the COV's recognition that there are difficulties bringing these communities together. The COV found that in many instances social sciences were interpreted as "societal impacts" in proposals. The COV also found the definition of social sciences to be somewhat narrow to date, focusing primarily on quantitative social sciences. The COV recommends that the program's view of relevant social sciences be expanded to include rigorous qualitative as well as quantitative methods. In addition to developing ever more complex models of natural and human coupling, research should increasingly attend to more sophisticated surveys and analyses of human (inter)actions, processes, values, and decisions that can help elucidate biocomplexity, but that cannot be adequately captured in quantitative models.

The COV recognizes that the current BE Priority Area ends in 2005 and the future structure for the multidisciplinary research that the BE competition has fostered is uncertain. NSF staff indicated that there is a commitment to continue support as a cross-cutting multidisciplinary area. However, the COV cannot emphasize strongly enough that it is important for NSF to continue its support of environmental research that goes beyond current disciplinary and educational research frameworks. An important question for NSF to consider as it launches new interdisciplinary, cross-cutting programs is how it will sustain the new communities once they germinate. An understanding of the realistic time frame for maturation of interdisciplinary teams and communities must be incorporated into the NSF management plan. Educational institutions are moving in the direction of BE, partly because NSF has fostered this research by providing funding and partly because the environmental challenges of the future demand this structure. Interdisciplinary efforts, including those undertaken by untenured professors, may become less attractive if the foci of priority areas change on time scales that are mismatched with time scales of major environmental problems and with the building and maturation of a scientific community able to address these problems.

Also of concern is the overall level of support for the BE solicitations, the success rate in proposal competitions, and the average funding level of an individual BE researcher. These concerns could also apply to other priority areas envisioned for the future. When the success rate drops to some critical value (perhaps below 10% or even 20%), future solicitations lose significant community interest and participation. Low success rates place a burden on the entire system of proposal writers, proposal reviewers, and program staff. A key question is at what point is the solicitation no longer "efficient?" When the funding level per investigator drops below some critical threshold, BE runs the risk of no longer being a leader and catalyst, but rather a provider of supplemental funding for existing activities. The COV recognizes the dilemma that NSF faces, but recommends that this complex suite of variables be seriously evaluated in planning for future multidisciplinary programs.

Integrity and Efficiency of Program's Review Processes. The COV was impressed with the integrity of the BE award process. Conflicts of interest were dealt with according to NSF guidelines. The topical area team members go to great lengths to populate panels with reviewers having the appropriate breadth and depth of expertise and diversity. According to BE team members, they look for reviewers with the appropriate "fuzzy edges," who are able to cross disciplinary boundaries. Although not voiced by the BE team leaders, the COV was concerned that the "fuzzy edges" population might be small and that "burn out" of reviewers could eventually become a problem. The COV recommends that NSF recruit reviewers from other new, cross-cutting programs. COV members specifically suggested that graduates from IGERT programs would good new reviewers. It was noted that the experience gained by new researchers who serve on these interdisciplinary panels, along side more experienced members, provides them with important training in interdisciplinary reviewing and research. The inclusion of new scientists, minority scientists, and scientists from minority and four-year colleges in these review processes is actually a mechanism for entraining them into interdisciplinary research and education.

The efficiency of the review process was excellent. The time from submission to notification of an award or a decline was almost always less than 6 months. The only exceptions were the decline process for the largest of the topical areas (CBC) in 2001 and the award process in 2003, when the Congressional budgeting process made decision-making impossible until late in the fiscal year.

The review process documentation often included individual ad hoc (mail) reviewers and always included reviews from at least three panel members, a panel summary written by one of the reviewing panelists, and a Form 7 written by a program officer to summarize the entire review process. Although most of the documentation was thorough, there was considerable variability in the level of detail from jacket to jacket. The COV found that panel summaries were sometimes incomplete with regard to details of the panel discussion. Although this incompleteness is understandable given the fast pace of panels, the panel summary is really the only written document that synthesizes NSF's evaluation of a proposal for the PI. It is therefore essential that panelists always write complete and accurate panel summaries, and that NSF staff remind panelists of this obligation and ensure that it is discharged. Also, the COV found that some Form 7s were not well documented regarding the final post-review award/decline decisions for proposals in the "fundable" category. Total numbers of fundable proposals always substantially exceeded funds available. It was not always made explicit what criteria NSF teams used to make the final decisions to award or not to award some of the proposals categorized as fundable by reviewers and panel. Although the BE team leaders uniformly said that extensive discussions were held during panel and in the post-panel team meetings, they agreed that the panel summaries and Form 7s did not always capture the essence of these discussions. Competing responsibilities for program officers' time may again be the culprit with the uneven details in Form 7s. The use of a program assistant as recorder, both in the panel and post-panel discussions, could help provide the additional documentation. The COV recommends that the final award and decline decisions be documented consistently and in sufficient detail to make the decision process clear to a COV member when reviewing jackets. The COV also recommends that necessary staffing is allocated to make this possible.

One issue that affected the efficiency of the COV review, and that could also affect the efficiency of the ad hoc and panel reviewers was the difficulty in easily discerning the number, identity, and composition of all members of the research team (institution, gender, membership in underrepresented groups, new vs. established co-PI, international affiliation if a collaborator from outside the US, etc.), understanding the role and tasks of each researcher participating in the interdisciplinary project, and the dollars requested by each participant. The COV recommends that

BE proposals have an additional form or table, not counted against the page limit for project descriptions, that clearly identifies each participant (i.e., PI, co-PI, Senior Person, collaborator, consultant, and named junior persons or trainees), her/his institution, area of expertise, brief statement of her/his contribution to the research, and dollars requested. (A summary table like this is required for proposals submitted to the interagency National Ocean Partnership Program, NOPP). Such a summary table would not only ease the assessment of the inter-disciplinary, inter-institutional, and international dimensions of proposals during the review process, it would also enable program staff to track what fields of science are being supported by cross-directorate initiatives.

The COV notes that although all BE proposals included an educational component that could have been discussed under Criterion 2, most of the written individual and panel summary reviews did not address Criterion 2 in great depth. The COV believes that lower emphasis on Criterion 2 is not a BE-specific issue, but an NSF-wide issue. It is noteworthy here, however, because the proposals were so rich in Criterion 2-related activities. The NSF team leaders noted that the education component was discussed in panel and was important in decision making, although the written documentation does not always reflect such discussions. Suggestions for addressing this problem in written reviews include: (a) redesign of the review form on Fastlane so that reviewers are asked to more fully address the individual questions under Criterion 2 as well as any specific review criteria required by the solicitation; (b) posting online of generic exemplary reviews, both good and bad; (c) clear and repeated guidance to the panelists to address Criterion 2 and other solicitation-specific criteria.

Integrity and Efficiency of Program's Management. Topical team members are the heart and soul of BE. The quality of the review process is a product of the quality and expertise of the team members. It is through their cooperation, each coming from a strong background in some disciplinary science, and commitment to expanding boundaries that the high quality of these topical areas is maintained. However, team members are under enormous pressure from above and below. Despite these pressures, they make the program work and are directly responsible for its success. Special competitions such as BE add to an already demanding workload. Somehow team members are able to reconcile conflicting programmatic demands and time commitments. After discussions with team members, the COV believes that release time and increased staff support are needed to avoid "burn out" amongst BE team members. The COV strongly advises NSF to seriously review the management structure with an eye to efficient and sustained use of NSF's greatest resources – the program officers (please refer to COV response to Question B4).

There is uniform agreement that the budgeting process for BE is unwieldy, burdensome, and markedly inefficient. The budget process requires an inordinate amount of BE staff time, increases stress, and is a major impediment to efficient management. The COV questions why such a universally disliked process remains in place. Is it a result of the NSF budgeting structure, where most monies reside in programs while BE is a cross-disciplinary activity? The COV recommends that NSF explore options for improving the budgeting process, not only to improve BE, but to provide improved efficiency for future cross-cutting activities.

Another concern raised by BE team members is the lack of BE funding for site visits to permit follow-up assessments for large projects funded through BE. Funds for site visits often must come from the "day job" of team leaders or members (and competed with limited program or division funds). Although the BE principal investigator workshops allow some level of assessment of funded projects, the COV recommends that funds be set aside to allow for site visits of large BE projects.

Improving the COV Process. The charge to the COV to evaluate the BE Competition in two and a half days, including the examination of 150 proposal jackets and considerable other relevant material, was quite daunting. To make such review efforts more feasible, it is critical that NSF look closely at the template questions and ensure that they are relevant to the program under review and that the material required to answer the questions is **easily available**. There were several questions that the COV could not address either because data were not available or the question was not appropriate for a multi-disciplinary activity such as BE. Sometimes the committee spent considerable time before it came to the realization that these questions could not be addressed. This time lost caused stress and frustration for the COV. For example, questions under section A4 could not be answered due to lack of data, specifically those addressing the "appropriate balance" questions for geography, types of institutions, under-represented groups, new investigators. Data were also not available to answer questions about interactions with related programs and comparisons to other cross divisional programs.

The COV recommends the following actions to improve the process in the future, particularly in preparation for the two broad multidisciplinary COVs that are soon to follow (*Nanoscale Engineering and Science* and *Information Technology Research*):

1. summary material and tables available in advance in an organized fashion (COV members couldn't easily determine what new material was recently added to the COV web site);
2. better organization of materials in the COV binders;
3. more time with team leaders, possibly in subgroups, to better understand challenges of cross-cutting competitions;
4. more time with the jackets (only possible if the remainder of the process is very efficient);
5. a separate table in future proposals to cross-cutting programs that lists who, where, what (contribution) and how (much money) to follow the cover page;
6. accessible data on items requested, which evidently were not accessible across directorates;
7. data on co-PIs, which may not be available because they are officially subcontractors and not co-PIs.

2.0 BE COV PROCESS (February 25-27, 2004)

The COV for NSF's BE competition met at NSF on February 25-27, 2004, to review the research programs in the five topical areas (CNH, CBC, GEN-EN, IDEA, and MUSES). The COV was instructed in NSF's conflict of interest policy and given its charge on the morning of the first day. Margaret Cavanaugh, the head of the Working Group for Environmental Research and Education (WG-ERE) that provides high level management for BE, and Joan Roskoski, who led the BE competition in FY99 and FY00, provided an overview of BE. They outlined the early activities that were the precursors of BE, the initiation of priority areas, the establishment of the WG-ERE, which among other things sets policies for BE, and the creation of the Advisory Committee for Environmental Research and Education (AC-ERE). The presentation also discussed BE's early years (1999 and 2000), the initiation of the five topical areas and integrative elements (i.e., quantitative approaches, education, and global perspective), and a short discussion of major accomplishments and issues. H. Lawrence Clark of Ocean Sciences took the committee through a detailed look at the COV template and pointed to sources of information relevant to the various questions.

One of the major tasks of the COV was to evaluate the proposal review process. To do this, the committee had access to 150 proposal jackets, a sample from the 850 proposals submitted to the BE competitions during the three years under review. These jackets were selected using the following procedure. There was a proportional allocation (based on the number of proposals) of the 150 proposals to the various topical areas. In each topical area an equal number of awards and declines were selected. One third of the awards and declines were "clear" awards and declines, based on high or low review scores. Two thirds of the awards and declines were selected randomly based on review panel scores from the "gray" area. This category included proposals with scores that were not necessarily clear awards or clear declines.

In the afternoon of day one the committee split into two groups to review proposal jackets. The two groups were organized by topical area. One group reviewed jackets from CNH, MUSES and IDEA and the other group reviewed jackets from CBC, GEN-EN and IDEA. This division of labor was used to facilitate review of the jackets. Each committee member was asked to review 15 jackets. Although a committee member could review more than the assigned 15 jackets if time permitted, some COV members reviewed less than 15 jackets due to the steep learning curve required to navigate the jackets. In addition to jackets, other material was available for review. These included project reports, summary statistical tables and graphs relating to many of the COV questions, and other relevant information provided on the BE COV web site.

The committee reconvened at the end of day one to discuss jacket reviews, ask questions, and prepare for meetings with topical area team leaders and team members the next morning. The COV spent some time in the morning on day two continuing jacket review. Two hours were spent with the topical area team leaders and representatives from EHR and INT. The plan had been to meet the NSF program officers included in BE reviews without management. However, because some of the topical team leaders are also members of the managing WG-ERE, it was not possible to do so. Nevertheless, the COV felt it received candid opinions on management and other issues associated with BE in follow-up discussions and emails. Team leaders and members attending the morning meeting included Thomas Baerwald – CNH, Donald Rice – CBC, Matthew Kane – GEN-EN, William Zamer – GEN-EN, Joan Frye – IDEA, Donald Burland – IDEA, Delcie Durham – MUSES, Frances Li – international resource for BE, and David Campbell – education resource for BE.

On the afternoon of day two the committee convened to begin drafting the COV report. Each member of the COV was assigned as a scribe for specific questions of the COV template. These scribes were not responsible for answering the questions, but for capturing the discussion in committee and providing text to the co-chairs. Until the end of the review on the afternoon of day three, the committee continued to review jackets and other materials, develop consensus answers to the COV questions, and write the report. At noon on day three, the COV presented its draft recommendations and findings to Margaret Leinen, Assistant Director for Geosciences (AD/GEO); Dr. Leinen is also the AD responsible for the Biocomplexity in the Environment initiative.

The COV was ably assisted by numerous NSF staff and we wish to thank all of those involved for their support. In particular, we would like to thank Margaret Cavanaugh and H. Lawrence Clark for bringing this hard working committee together, Mary Mosley for logistical arrangements, Melissa Lane for pulling together all of the information we requested, and the science assistants Robyn Smyth and Sayuri Terashima for arriving early, staying late, taking notes, and cheerfully assisting us with our numerous questions.

3.0 PART A. COV TEMPLATE: INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

3.1 A.1 Questions about the quality and effectiveness of the program's use of merit review procedures. Provide comments in the space below the question**.** Discuss areas of concern in the space provided.

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCEDURES	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Is the review mechanism appropriate? (panels, ad hoc reviews, site visits) Comments: Peer review panels were constituted to review proposals in all five of the topical or thematic areas of BE. There were differences among the different topical areas with regards to the use of outside mail reviews. Seven directorates and two offices were involved in this cross-cutting effort; the mechanism of a specific review reflected the practices of the directorate leading that review. The larger proposals were reviewed by interdisciplinary panels with generally four or more written reviews, in addition to a consensus panel summary. The smaller planning proposals were commonly reviewed by a panel made up of NSF program directors who were not involved with the BE review process; this group included both permanent NSF scientific personnel and rotating scientists. A similar process of written individual reviews and a summary recommendation was used by this internal review. In summary, a rigorous peer review mechanism was in place for these competitions.	**Yes**
2. Is the review process efficient and effective? Comments: The efficiency of the review process was very good. The time from submission to notification of an award or a decline was almost always less than six months. The only exceptions were the decline process for the largest of the topical areas (CBC) in 2001 and the award process in 2003, when the Congressional budgeting process made decision-making impossible until late in the fiscal year.	**Yes**

3. Are reviews consistent with priorities and criteria stated in the program's solicitations, announcements, and guidelines? Comments: The written reviews reflected well the solicitations, announcements, and guidelines. There seems to be a strong commitment by the reviewers to make this a successful interdisciplinary competition. The reviewers in the various topical areas sometimes wrestled with the definition of "biocomplexity" as it related to the individual topical areas, but the reviews showed a good general understanding of the goals of the topical areas as described in the program announcement. Both ad hoc and panel reviewers were conscientious in evaluation of Criterion 1. However, one recurrent problem was the uneven attention by panelists and mail reviewers to Criterion 2 and to the special criteria for the various BE competitions. This unevenness in attention appeared due not to any failure on the part of NSF, but the inability of reviewers to understand these criteria or uncertainty or unwillingness to evaluate the proposals in light of these criteria. In the COV discussions, it was noted this is not a BE-specific issue but an NSF-wide issue. Some suggestions for addressing this problem include: (a) redesign of the review Form on Fastlane, so that reviewers are asked to more fully address the individual questions Criterion 2, as well as any other program-specific review criteria, in separate response fields; (b) posting online, or providing, generic models of reviews, both good and bad; (c) clear and repeated guidance to the panel to comment on all criteria. During the interview with the Team Leaders for the BE competitions, they noted that the other criterion were discussed in panel, even when reports of such discussions were not captured in written panel summaries or Form 7s.	**Yes**
4. Do the individual reviews (either mail or panel) provide sufficient information for the principal investigator(s) to understand the basis for the reviewer's recommendation? Comments: Individual reviews range widely in quality and detail. Overall, most of the reviews provide needed feedback to the investigators, but there are some cases where the information in the review is overly curt or lacking in conciseness and clarity. It is suggested that ad hoc/mail reviewers and panelists receive generic examples of well-prepared and poorly-prepared reviews (or a URL pointing to such examples) along with their proposal assignments as guidance. Heterogeneity in reviews is a fact of life, but it is recommended that thorough and appropriate reviews be recognized and encouraged at all stages of the review process.	**Yes**

5. Do the panel summaries provide sufficient information for the principal investigator(s) to understand the basis for the panel recommendation? Comments: In many cases, the panel summaries are written with adequate information for the principal investigator to understand the basis for the decision. However, the COV was sufficiently concerned that there was enough variability in the panel summaries in the various BE programs that a few additional comments are warranted. The panel summary provides the principal investigator with the most detailed written documentation on the panel's assessment of a given proposal. It is critical that the panel summaries capture the major points of the panel and communicate them to the principal investigator(s). It is important that panel summaries provide more than "one line statements" as justification to the principal investigators in order to provide investigators with useful information to improve their proposal or succeed with future NSF proposal solicitations. The COV recognizes the dynamics of a typical panel and the time constraints/difficulties involved in capturing the scope of a panel discussion, but it is the responsibility of the program officer and panel leadership to ensure that thorough documentation is achieved so that it can be passed on to the investigator(s). The following needs to be brought home emphatically and repeatedly to panelists: "Put yourself in the shoes of a PI who has invested months preparing a proposal and who will receive the panel summary as the only written record of panel review. Would you be satisfied by what you have written as a panel summary?" The COV also recommends that future panel members be provided with exemplary models of panel summaries, both good and bad, to serve as guidance in addition to a template. Another suggestion is to have a program assistant take notes during the panel discussion and provide the panelist in charge of the summary with the main points of the panel discussion. The time element is often the culprit for terse panel summaries.	**Yes**

6. Is the documentation for recommendations complete, and does the program officer provide sufficient information and justification for her/his recommendation? Comments: The Form 7 is the primary documentation that the program officer utilizes to provide information and justification for the BE proposal recommendations. In general, the jacket information reviewed by the COV was thorough, and the Form 7s were effective. However, there was some variability in the details provided among the Form 7s, and the COV identified rather vague language at times that did not fully explain the justification for a decision. Since Form 7s are internal NSF documents, more explicit information should be included in the Form 7s to more fully explain the justification for the proposals that were ultimately funded. In COV interviews, the team leaders remarked that there are extensive discussions in the panel and in team meetings after the panel, including ranking and prioritization of proposals, but that these activities are not fully reflected in the jackets. The COV feels that these should be reflected in the Form 7 or other documentation. One specific problem is the following rationale found in some Form 7s: "Funds were not sufficient to fund the proposal." This statement provides no record of the considerations that led to a proposal's declination in relation to other proposals. For example, it should be clear why a specific proposal (given a set of similarly ranked proposals) was chosen to achieve portfolio balance (e.g. discipline balance, geographic balance, etc.) The COV recognizes the extraordinary time devoted by the program officers involved in these complex interdisciplinary reviews, and suggests that a mechanism – that does not further burden the program officers – be found to provide more uniform documentation of the basis for decision making. One suggestion is to include a summary overview for each panel that captures the rationale for funding decisions in all jackets from that panel.	**Yes**
7. Is the time to decision appropriate? Comments: The COV felt that the time to decision is appropriate (in almost all cases the time to decision was less than six months). In FY03 when the time to decision for funded proposals was longer, it was because of Congressional delays in finalizing the budget.	**Yes**

8. Discuss issues identified by the COV concerning the quality and effectiveness of the program's use of merit review procedures:

In general, the COV felt that the BE's merit review procedures are of high quality and effectiveness. A few issues were raised that could enhance the process:

- Post-award site visits are needed but are limited by programmatic and budget restrictions and competing demands on Team Members' time.
- Individual and panel reviews, at times, were not consistent with respect to Criterion 2 and program-specific criteria. Criterion 1 seems to be the dominant if not sole consideration in many review documents. Team members reported that discussions on the other criteria were held at the panel, although they were often not documented.
- It is critical that the panel summaries capture the major points of the panel and communicate them to the principal investigator(s). It is important that panel summaries provide more than "one line statements" as justification to the principal investigators in order to provide investigators with useful information to improve their proposal or succeed with future NSF proposals. Note taking by program assistants at the panel, with notes provided to the panelist responsible for writing the summary, might better capture the essential points of discussion.
- In light of the previous issues, exemplary generic reviews and panel summaries, both good and bad, should be provided to individual reviewers and panelists when they receive proposals and at panel meetings as guidance to reduce the variability in review scope, length, and content.
- Since Form 7s are internal NSF documents, more explicit information should be included in the Form 7s to explain the justification for the proposals funded. For example, the program officer should explicitly state why a specific proposal was funded, given a set of similarly ranked proposals. In COV interviews, the team leaders remarked that there are ranking and prioritization activities that occur in panels and at team meetings after panels that are not reflected in the jackets. The COV feels that these activities should more routinely be reflected in the Form 7 or other documentation.
- The necessary staff support, either as release time from other duties or through help from qualified program assistants, should be provided to the Team Members to give them the time to write up additional documentation. The NSF program staff should be commended for doing an excellent job under so many competing demands for their time.

3.2 A.2 Questions concerning the implementation of the NSF Merit Review Criteria (intellectual merit and broader impacts) by reviewers and program officers. Provide comments in the space below the question. Discuss issues or concerns in the space provided.

IMPLEMENTATION OF NSF MERIT REVIEW CRITERIA	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
9. Have the individual reviews (either mail or panel) addressed whether the proposal contributes to both merit review criteria? Comments: Intellectual Merit is reasonably covered, although there is variability in the depth of the reviews. Broader Impacts is often not covered in sufficient detail. See 12, below.	**No**
10. Have the panel summary reviews addressed whether the proposal contributes to both merit review criteria? Comments: Intellectual Merit is reasonably covered, although there is variability in the depth of the reviews. Broader Impacts is often not covered in sufficient detail. See 12, below.	**No**
11. Have the *review analyses* (Form 7s) addressed whether the proposal contributes to both merit review criteria? Comments: Intellectual Merit is reasonably covered, although there is variability in the depth of the reviews. Broader Impacts is often not covered in sufficient detail. See 12, below.	**Yes**

12. Discuss any issues or concerns the COV has identified with respect to NSF's merit review system.

With regard to the quality of Intellectual Merit evaluations by individual reviewers, panel summary reviews, and Review Analyses (Form 7s), most COV members thought the Form 7s were generally excellent, but noted there was considerable variability in individual and panel summary reviews. At least one member of the COV felt that these reviews were less than would be expected for a grant of BE magnitude and, indeed, than often found in disciplinary-based programs. In part, the variability in the depth of the reviews may be a function of the high degree of interdisciplinarity of the proposals and the more narrow expertise of many of the reviewers, particularly in light of the guidance given in the Program Solicitations – i.e., that each reviewer is asked to address only components "for which he/she is qualified to make judgments."

Responses to the Broader Impacts criteria require more discussion. Responses are highly variable in terms of individual, panel, and Form 7 reviews. The following observations are relevant.

1. NSF has made strenuous effort to increase awareness of the Broader Impacts criteria, the seriousness with which it needs to be addressed, and actions that are encompassed by or might satisfy the criterion. In this regard, the COV Committee noted a distinct improvement in reviews over the three years of BE. The COV also found it heartening that PIs, proposals, and research projects address Broader Impacts as fully as they do.

2. Most COV members felt written reviewer/programmatic responses to Broader Impacts are much less compared to those for Intellectual Merit, and are insufficient in general. One or two lines are often the extent of the response; specifics such as those found under Intellectual Merit are rare and critical observations were rarely encountered. However, there was variability and some proposals garnered more detailed reviews than others. In discussions with the Team Leaders, they noted that no proposal rose to the top without high Intellectual Merit. However, they also noted that within this group of highly meritorious proposals, the quality of the "Broader Impacts" played a distinct and defining role in making decisions (although these discussions were often not documented in the panel summary or Form 7s).

3. The variability in responses to Broader Impacts is of three types. One dimension appears to be the lack of clarity in the individual reviewer's **understanding** of what is a "Broader Impact." Is it K-12 or institution-based (e.g., museums) education; training undergraduates, graduates, or post-docs; impacting policy; presenting a new technology or software that is significant to other endeavors; impacting one's field, science, or society; or other attributes? A second dimension of variability is how individual reviewers and programs **evaluate**, and **articulate** their evaluation of, "Broader Impacts." A third dimension is the lack of knowledge of reviewers as to the weight placed on "Broader Impacts" in final funding decisions.

4. How might the depth of response to Broader Impacts be increased, NSF-wide? The COV thought that NSF could undertake a "definition" effort, much like that undertaken to define or understand better the scope and content of "biocomplexity." This definition should then be disseminated to the science community as part of the merit review criteria, but also articulated in a review template. In this regard, Intellectual Merit is well understood because scientists are inculcated through their respective disciplines. The Broader Impacts criterion is more difficult, because we approach its definition as citizens with highly variable backgrounds and perspectives.

3.3 A.3 Questions concerning the selection of reviewers. Provide comments in the space below the question. Discuss areas of concern in the space provided.

SELECTION OF REVIEWERS	YES , NO, DATA NOT AVAILABLE, or NOT APPLICABLE
13. Did the program make use of an adequate number of reviewers for a balanced review? Comments: The mandated minimum of 3 reviewers was always met; often many more reviews were submitted. The COV felt that more reviewers than three would be desirable as the norm. Ideally at least one reviewer should be expert in each represented discipline and at least one reviewer should be a "broad" thinker or from an interdisciplinary background, because many BE proposals are highly diverse in the disciplines they represent. For programs that use only the panel (and not mail) reviews, the COV suggest that proposals be assigned to a minimum of four panelists. Because the review community is typically inundated with requests to review, the programs that use ad hoc/mail reviewers suffer the NSF-wide problem of lack of responsiveness to requests for review This committee's response is largely based on ad hoc examination of selected jackets. Ideally, future COVs should be provided with frequency distributions of numbers of reviewers for each proposal and within each theme. The COV recognizes this may be challenging because, while the BE program spans many NSF Divisions, some of the databases do not.	**Yes**

14. Did the program make use of reviewers having appropriate expertise and/or qualifications? Comments: NSF Team Leaders and other BE staff articulated the concept of reviewers "with fuzzy edges," meaning reviewers who were already interdisciplinary or interacted with multiple disciplines. As much as possible, Team Members attempted to incorporate such people into advisory panels and use them as ad hoc/mail reviewers. The COV was impressed with the high quality and interdisciplinarity of reviewers. There were, however, two noteworthy areas for improvement: 1. For those programs in which tool development is a major objective, panels should make greater efforts to include more representatives from the private sector. Without such representation, NSF might duplicate funding on projects that are already underway in the private sector and in which the private sector will succeed first. 2. Panels and ad hoc/mail reviewers often lack specific expertise in areas covered by "Broader Impacts" (e.g. education, public outreach, international programs, etc). Team Members representing EHR and International Activities reported that they were consulted on Panel composition. From information provided at the COV, it was impossible to determine to what degree these suggestions were implemented. However, team leaders indicated that on a number of panels expertise in education was represented. The COV recommends that all BE panel membership should include individuals with expertise in criteria relative to the specific solicitation including science education and dissemination.	**Yes**

15. Did the program make appropriate use of reviewers to reflect balance among characteristics such as geography, type of institution, and underrepresented groups? <u>Comments in terms of panelists:</u> Geography: Yes, good balance was achieved. Type of Institution: No. Reviewers were almost exclusively from large universities. From the subset of proposals reviewed by the COV, only one panelist from a four-year college was noted, and only one from industry. As stated in the response to item #14, this low representation from industry is problematic. Team leaders responded that in some cases (e.g, Gen-En), only individuals at large universities were likely to have the experience with expensive techniques that made them competent panelists. They thought, however, that this balance would change as BE research became more widespread. Underrepresented minority groups and gender balance: Insufficient information to determine. The COV recognizes that the lack of data is a consequence of the database structure; while the BE program spans multiple NSF Divisions, some of the databases do not. <u>Comment in terms of ad hoc/mail reviewers:</u> No information on balance was provided to the COV. The COV recognizes that the lack of data is a consequence of the database structure; while the BE program spans multiple NSF Divisions, some of the databases do not.	**Data not available**
16. Did the program recognize and resolve conflicts of interest when appropriate? Comments: COI resolutions were well documented. A panelist with a COI did not participate in the evaluation of a proposal or any discussion relating to the proposal. No evidence of mail reviewers with conflicts was observed.	**Yes**
17. Discuss any concerns identified that are relevant to selection of reviewers. Concerns are included in the above comments under questions 13 – 16.	

3.4 A.4 Questions concerning the resulting portfolio of awards under review. Provide comments in the space below the question. Discuss areas of concern in the space provided.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
18. Overall quality of the research and/or education projects supported by the program. Comments: The program is only in its initial years, and thus even the oldest awards in the portfolio have not reached their conclusions. Nevertheless, the COV notes that, even in this short time, numerous impressive outcomes are evident in the portfolio of awards, both in terms of scholarly publications and broader impacts. Examples of these quality outcomes are presented in Section B.	**Yes**
19. Are awards appropriate in size and duration for the scope of the projects? Comments: The COV raises the question of whether the size of the BE budget overall and, consequently that of the average BE award, is large enough to accommodate the type of multi-PI proposals being put forth to meet the complex interdisciplinary nature of the research under this competition. The COV also recognizes the necessity to balance award size with the maintenance of a reasonable funding success level. Team Members continually deliberate on the optimal balance of these considerations. That said, the COV notes that reviewers and program officers have been effective in scaling back the proposals (where necessary) and allocating appropriate funds to create proper balance between the scope of projects and size of awards.	**Yes**
20. Does the program portfolio have an appropriate balance of: • High Risk Proposals? Comments: By virtue of the cross-directorate structure and interdisciplinary nature of the BE program, the proposals in the competition and the awards in the portfolio are inherently risky, particularly in comparison to more traditional proposals and awards seen in other program portfolios.	**Yes**

21. Does the program portfolio have an appropriate balance of: • **Multidisciplinary Proposals?** Comments: By virtue of cross-directorate structure and interdisciplinary nature of the BE program, the proposals and the awards are inherently multidisciplinary.	**Yes**
22. Does the program portfolio have an appropriate balance of: • **Innovative Proposals?** Comments: The BE program and the field of research it has inspired are themselves new, and thus the proposals and the awards are innovative in general and overall.	**Yes**
23. Does the program portfolio have an appropriate balance of: • **Funding for centers, groups and awards to individuals?** Comments: The awards were made to teams of individuals. Although the management plan and BE solicitation state that some of the funding could go to individuals who work in larger (interdisciplinary) groups, awards to single PIs weren't made because of the nature of BE research and program goals. Although university centers have begun that are related to this research, no money was awarded from this program for the establishment of formal centers.	**Yes**
24. Does the program portfolio have an appropriate balance of: • **Awards to new investigators?** Comments: Only data on the lead PIs are available, so it appears as if BE primarily funded senior investigators. Limited Co-PI data are available, so this question could not be answered. These data are not readily available to NSF, because the data exist in different divisional databases or are not presently captured. The COV recognizes that the lack of data is a consequence of the database structure; while the BE program spans multiple NSF Divisions, some of the databases do not.	**Data not available**

25. Does the program portfolio have an appropriate balance of: • **Geographical distribution of Principal Investigators?** Comments: The COV was unable to address this question. Some EPSCoR data was available, but these data are inconclusive because they do not fully reflect national geography – EPSCoR and non-EPSCoR states are distributed in all geographic regions. This information is in the award/decline spreadsheet, but needs to be collated. The COV could better answer this question if the data were extracted and provided as part of the meeting materials. However, because of the lack of data on Co-PIs, even this statistic would not reflect the true geographic distribution of the totality of BE investigators.	**Data not available**
26. Does the program portfolio have an appropriate balance of: • Institutional types? Comments: The data are not really available to the committee without manually extracting them from each jacket. The furnished spreadsheet shows the institutions, but we don't have all the individual designations of all the types of institutions. NSF should make these data more easily available. However, because of the lack of data on Co-PIs, this statistic on PIs alone would not reflect true participation of BE investigators from all institutional types.	**Data not available**
27. Does the program portfolio have an appropriate balance of: • **Projects that integrate research and education?** Comments: Biocomplexity in the Environment is a new program with an explicit criterion to integrate research and education. The tasking is clear; capturing the outcomes will be more difficult. Results from an NSF-funded workshop on integrating education in biocomplexity research should help. Diversity of the education projects was noted, and in some cases, stellar. In other proposals, the educational component was not as well developed as the research project. The COV members were informed by the team leaders that if the integration of research and education was not in the proposal, it would not be funded. The funded proposals all do integrate the research projects with different types of education. Educational activities include K-12, undergraduate (especially research experiences), graduate and informal education in public venues.	**Yes**

28. Does the program portfolio have an appropriate balance: • **Across disciplines and subdisciplines of the activity and of emerging opportunities?** Comments: This is definitely a great strength of this program. Each core team has recruited its own set of program directors from a variety of the NSF Directorates. Sometimes there are numerous representatives from one directorate, for example, Ocean Sciences, Earth Sciences and Atmospheric Sciences from within the Geosciences Directorate. The portfolio of grants awarded reflects this diversity, with one home for the grant jacket for funding, but with the funds often coming from a variety of Directorates. This has taken the research effort into true collaboration and has allowed groups to respond to emerging opportunities, especially with the development of new tools in genomics, bioinformatics, social sciences, satellite imagery, etc. The portfolio is a unique selection of interdisciplinary approaches, of integrative research with modeling, visualization, simulations and quantitative approaches being used.	**Yes**
29. Does the program portfolio have appropriate participation of underrepresented groups? Comments: There are no data to support a finding about "appropriate" participation for this cross directorate program. Some data has been gathered that suggests the minority success rate for the Principal Investigators is not statistically different from non-minority PIs. Female PI success rates are not statistically different than male PI success rates. Also note comments under Questions 24–26 regarding database limitations.	**Data not available**

30. Is the program relevant to national priorities, agency mission, relevant fields and other customer needs? Include citations of relevant external reports. Comments: This program is highly responsive to a great need for integrative research to answer non-linear complex questions. The outcomes are helpful to establishing sound science evidence for use in policy decisions, in making science relevant to the community, in including the human dimension in consideration of environmental change, and in integrating these areas of science knowledge and discovery with the need for environmental literacy among our students in formal education and the education of the general public. This program is relevant to national needs and addresses many of the issues raised in documents such as: *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change* (U.S. Global Change Research Program, 2001). *Environmental Science and Engineering for the 21st Century* (National Science Board, 2000). *Expanding the Human Frontiers of Science: Bringing Minority-Serving Institutions into the Mainstream* (National Science Foundation, 2001). *Grand Challenges in Environmental Sciences* (National Research Council, 2001). *In Pursuit of a Diverse Science, Technology, Engineering and Mathematics Workforce* (American Association for the Advancement of Science, 2001). *Nature and Society: An Imperative for Integrated Environmental Research* (lsweb.la.asu.edu/akinzig/report.htm, 2001). *NSF Geosciences Beyond 2000: Understanding and Predicting Earth's Environment and Habitability* (National Science Foundation, 2000). *Our Common Journey: A Transition to Sustainability* (National Research Council, 1999). *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States* (The H. John Heinz III Center for Science, Economics, and the Environment, 2002). *Teaming with Life: Investing in Science to Understand and Use America's Living Capital* (President's Committee of Advisers on Science and Technology, 1998).	**Yes**

31. Discuss any concerns identified that are relevant to the quality of the projects or the balance of the portfolio.

The COV was impressed by the very high quality of the proposals funded, by the leadership of the thematic team leaders, by the care and dedication of the team members in the panels and follow-up team meetings, and the excellent stewardship in the distribution of funds.

The members of the COV were not able to answer a number of questions about the balance regarding participation of underrepresented groups and minority and four-year institutions. This exemplifies a general and recurrent issue in the analysis of BE: the relevant databases seem to be maintained *within* directorates whereas BE activities are *among* directorates. This issue needs to be anticipated in the implementation of future cross-directorate initiatives.

3.5 A.5 Management of the program under review. Please comment on:

32. Management of the program.

Comments:

The formal BE competition is a cross-directorate activity with five sub-themes or topical areas. The management of BE is an ongoing process and a complex one, involving seven directorates and two offices. As a consequence of the complexity, the management structure requires extraordinary work by the NSF staff, particularly in context of the overall size of the funds managed. It should also be noted that the COV did not review the "unfenced" components of the BE budget, only the proposals submitted in response to the formal or "fenced" BE competitions.

Corresponding to each interdisciplinary theme is a team that provides interdisciplinary management of the review process. Each Team has a team leader and team membership is drawn from many programs across the Directorates. Supervising the teams and providing integration is a Working Group (WG-ERE). The COV has been provided with a management plan for FY2003. This plan both provides openness and flexibility and is cognizant of NSF's operating culture. As is evident from the plan, lessons have been learned as BE has developed. For example, the sub-themes are now relatively stable after initially varying from year to year.

A more thorough analysis of management issues is covered in section B.4, *Outcome Goal for Organizational Excellence*.

33. Responsiveness of the program to emerging research and education trends.

Comments:

The NSF BE program is not responding but actually is "leading the charge" in the field of biocomplexity, both in terms of stimulating new research directions and inspiring innovative education initiatives. The COV was impressed by the professional commitment and intellectual enthusiasm of the NSF program officers volunteering for BE, and noted reports from the staff that their dedication was motivated explicitly by the program's leading edge character. See Questions B1–3 for examples and evidence of the impact that the BE program has had on the emergence and evolution of this new field.

34. Program planning and prioritization process (internal and external) that guided the development of the portfolio under review.

Comments:

Considerable time and energy has been expended at the NSF to plan the Biocomplexity in the Environment (BE) crosscutting program. The Advisory Committee for Environmental Research and Education (AC-ERE) was constituted in 2000 and has provided advisory input, including the 2003 publication titled "Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century." The other reports, including external reports, referenced under question 30 were also part of the planning process. The Working Group for Environmental Research and Education (WG-ERE) is a NSF committee that meets regularly to formulate, plan, and guide BE. Program solicitations have been modified and adapted through the years of the competition to be responsive to the inputs of the community and program needs. The addition of MUSES to the portfolio illustrates the responsiveness of the program to developing new initiatives under the BE theme where appropriate. Overall, the BE program has had a high level of planning, involving a highly diverse set of programs within the NSF, to produce the current portfolio of awards.

35. Discuss any concerns identified that are relevant to the management of the program.

The COV recognized the difficulties that are inherent in the management of a cross directorate program of the size of BE. Several areas stood out as areas of tension, and certainly need some attention from the Foundation; a more thorough analysis of management issues is covered in section B.4, *Outcome Goal for Organizational Excellence*. Some of the needed changes involve the residence of the dollars for funding these proposals, the actual movement of the moneys, whether it be from the "fenced" and "unfenced" accounts, or just the availability for timely decisions for the funding cycle. It is clear that these difficulties have the potential to eat up valuable time from Program Directors. These Program Directors appear to mostly take on participation in the BE program as a volunteer "night job" that seems a bit beyond the call of duty. It would seem that much credit should be given to these individual for their heroic-scale efforts. It is clear that the National Science Foundation is understaffed, and that more support is needed to prevent burnout from seasoned program directors and sloppy attention from overextended program directors. We were continually amazed by the excitement of the Program Directors and team leaders for their established portfolio and the promises of the program. It is truly a portfolio that NSF can show with great pride. However, the long-term ability of NSF to maintain the high quality review and management of cross-cutting programs such as BE will require a serious investment by NSF in adequate staffing.

4.0 COV TEMPLATE B. Please provide comments on the activity as it relates to NSF's Strategic Outcome Goals. Provide examples of outcomes as appropriate. Examples should reference the NSF award number, the Principal Investigator(s) names, and their institutions.

4.1 B.1 OUTCOME GOAL for PEOPLE: Developing "a diverse, competitive and globally engaged workforce of scientists, engineers, technologists and well-prepared citizens."

Comments:

The BE program has been a catalyst in developing new linkages among researchers and educators, and has been a leader in creating new modes for training a cross-disciplinary workforce. Within the five thematic areas of BE, researchers have formed collaborations among groups that traditionally have not interacted in the past. We believe that this NSF priority area has been a catalyst for some universities to develop interdisciplinary centers for biodiversity (i.e., South Dakota Center for Biocomplexity Studies). At a symposium at the recent AAAS annual meeting in February 2004, a panel described BE projects that focus on the interplay between human and natural systems; of the six teams, only one existed before the CNH solicitation.

Examples from BE-funded projects are beginning to emerge that will guide future thinking for developing a cross-disciplinary workforce. During its short lifetime, the BE competition is having an impact on the development of a 21st Century workforce by changing the thinking among researchers from various disciplines, by offered new opportunities for undergraduate and graduate students who become engaged in the BE projects, by seeking participation from underrepresented groups, by increasing the participation of teachers in K-12 schools in research, and by fostering new venues to engage and educate the public in environmental science through informal education. The workshop report, "Integrating Research and Education: Biocomplexity Investigators Explore the Possibilities," published in 2003 by the National Academies Press will do much to further stimulate the integration of research and education. Another direct outcome of BE is the BioQUEST Curriculum Consortium – a new initiative to develop teaching strategies for integrating biocomplexity and its multidisciplinary approaches to problem solving in undergraduate education (http://www.bioquest.org16080/biocomplexity/).

The following projects are but a few examples of BE activities that show how established researchers have expanded their research domains through new collaborations fostered by BE. They provide a glimpse into a range of new educational activities that integrate education and research in K-12, undergraduate, graduate, and postdoctoral levels.

Thomas E. Graedel, professor of chemical engineering at Yale University, and colleagues are funded by a BE grant to study the anthropogenic cycles of steel and its associated elements (BES 0329470). To date, no multilevel linked cycles have been constructed for any technological materials, such as steel. Advances in metallurgy make it possible to produce a wide variety of steels with considerably enhanced properties, achieved through the alloys. Very little information on the material flow cycles of these alloy elements is available, especially on how those cycles are linked together, and on what the implication of changes in those cycles might be for resource availability, economics, the environment, and options for governmental policy. Graedel's research is using a dynamic material flow analysis model to study the linking of the alloying elements, as well as to trace the histories of the ferroalloy element use and to develop long-term scenarios for the future. In parallel, an economic model incorporating materials flows is being developed for the United States to explore market structure, costs, and related drivers as influences on future materials flows. A unique information

exchange has been created with a six-member advisory team of researchers from the steel industry, government, and academia representing Europe, Asia and the United States. Graedel stated that the BE program challenged him and his research colleagues, a geologist and a social scientist, to add an economist to their team to round out the team, something he would not have considered. To quote Graedel, "The BE program pushes us outside our comfort zone."

Marina Ratchford, American Association for the Advancement of Science, and her colleagues are addressing how human influences on land use, specifically fragmentation, is depleting spatial biocomplexity (INT 0119961). The goal of this project is to demonstrate the importance of spatial complexity, the costs of fragmentation, and to identify options for sustainability at sites around the world by linking ecological and socio-economic research, and in the process, create an international network of scientists addressing these issues. The project focuses on 21 sites in nine countries on four continents. The interdisciplinary scientific team includes ecologists, anthropologists, economists, and political scientists.

Gary Taghon of Rutgers University and his team are studying the roles of resources, competition, and predation in the microbial degradation of organic matter (OCE 0120453). This project includes mechanisms to enhance coursework in both undergraduate and graduate programs in environmental technology and engineering education; provides enrichment opportunities for in-service teachers of science courses in grades 5-8 through a partners-in-learning program; and broadens student research training by exploring dynamic interactions within and among environmental systems.

Steven Higgins of the University of Wyoming and his colleagues are developing robust multiplexed arrays of sensors for the detection of inorganic and organic analytes to quantify heterogeneous kinetics and molecule/surface interactions in complex, groundwater and surface water, and extreme ecosystems (DMR 0120007). This project provides students with educational opportunities in areas of high priorities to industry; the students trained through this program will be highly competitive in the job market.

Paul Flikkema and his team at Northern Arizona University are supported within the IDEA topical area. Not only are they are developing and deploying a wireless sensor network for better understanding of environmental and ecosystem processes across multiple scales (EF 0308498), but included in this project is an effort to broaden the cultural perspectives in the sciences among a large local minority population (Native American students) and through workshops to an international group of researchers.

4.2 B.2 OUTCOME GOAL for IDEAS: Enabling "discovery across the frontier of science and engineering, connected to learning, innovation, and service to society."

Comments:

The BE program also has been a catalyst in fostering new ways of thinking about the environment, stimulating the investigation of new linkages among different components of the environment, and making explicit the role of humans in the environment. The results presented at the first two Biocomplexity in the Environment meetings of principal investigators indicate that the program has been very successful in stimulating new ideas. A new international journal, *Ecological Complexity*, launched in 2004, is dedicated to biocomplexity. This journal reflects the intellectual excitement of this new field, and the content and vibrancy of such new initiatives will serve as barometers of the

impact of the BE program. Departments and programs in many universities are changing their compositions to realign themselves along biocomplexity themes. The GEN-EN competitions have stimulated more biologists to use novel molecular tools. As a direct outcome from one of the planning grants, a new Gordon Conference series on *Evolutionary and Ecological Functional Genomics* has been launched (http://www.grc.uri.edu/programs/2003/evolecol.htm). A long-term goal of the program is to improve science-based predictive capabilities for decision-making; reports from several projects indicate that BE results are being incorporated into local resource planning. In summary, BE has played a leadership role in stimulating good science. Some specific examples follow.

A BE-funded project has, for the first time, reconstructed multiple individual genomes from a microbial community taken from an environmental sample rather than a laboratory culture. An approximately five member microbial community is derived from a subsurface extreme acid mine drainage site within an ore body. These findings shed light on how bacteria and other microbes function collectively. The study leader, Jill Banfield, UC Berkley, said that this finding "takes the study of natural biogeochemical systems to a new level" (EAR 0221768). The study was also jointly funded by the DOE's Microbial Genomics Program.

Richard E. Lenski, Michigan State University, and his colleagues are investigating the emergence of biocomplexity and examining its consequences for the performance of living organisms and ecological communities, using a kind of artificial life to create a road map detailing the evolution of complex organisms (DEB 9981397). They define biocomplexity as the dynamic web of interactions among genes, organisms, and environments. Parallel experiments are being performed with two very different systems, in order to study general principles. One system employs bacteria, and the other system is digital. The latter consists of special computer programs that self-replicate, mutate, and evolve novel sequences of instructions to solve problems. One set of experiments will monitor the evolution of ecosystem complexity, in which a single progenitor diverges into multiple types that perform distinct functions by exploiting different resources. Follow-up experiments will examine the effects of removing member species on the remainder of the community. Another project will develop the software used for studying digital organisms into an educational tool. In Nature (8 May 2003) Richard Lenski and colleagues reported that the path to complex organisms is paved with a long series of simple functions, unremarkable if viewed in isolation, but understandable if viewed as a complex system.

A study by Alan Hastings at UC Davis and colleagues focuses on non-native species, one of the gravest threats to natural ecosystems and the maintenance of ecosystem services (DEB 0083583). The massive invasions of *Spartina alterniflora*, an Atlantic cordgrass, into Pacific estuaries, provide a window to the general ramifications of alien species in ecosystems. This project is an integrative study of dynamics of an invasive species, including a mathematical/conceptual model, physical and biological feedbacks, and a study of impacts on non-commercial human values.

Marina Alberti at the University of Washington and colleagues are studying interactions between urban development and ecological processes, using bird diversity as a test case for an integrated modeling approach (BSC 0120024). Urban development evolves over time and space as the outcome of interactions among individual choices and actions taken by multiple agents. These decisions affect ecosystem structure and function through the conversion of land, fragmentation of natural habitat use, disruption of hydrological systems, and modification of energy flow and nutrient cycles. This project is developing an integrated model of urban development and land-cover change in the central Puget Sound region. The advances made by the project in the development of the UrbanSim modeling

system have led to its adoption and use by the Puget Sound Regional Council, the region's growth-management and transportation planning authority.

Herbert Mascher, Idaho State University, and colleagues are addressing long-term ecological effects of human-salmon interactions in the southern Bering Sea (BCS 0119743). Catastrophic declines in many species including salmon, Steller sea lion, sea otter, and some pelagic birds show that this ecosystem is neither healthy nor sustainable given modern harvesting rates. Using biological and ecological data, paleoclimatic reconstructions, archaeological data on subsistence and harvesting rates, historic and modern catch and escapement records, ethnographic reports and traditional ecological knowledge, this project is using Swarm agent-based modeling routines to investigate the dynamics of human-salmon-ecosystem interactions in the southern Bering Sea region of Alaska. The multidisciplinary investigative team is developing methods to directly test a number of relationships associated with direct and indirect impacts of changes in one or more sets of human and/or natural systems on the others.

4.3 B.3 OUTCOME GOAL for TOOLS: Providing "broadly accessible, state-of-the-art S&E facilities, tools and other infrastructure that enable discovery, learning and innovation."

Comments:

The awards made under the IDEA theme of Biocomplexity in the Environment program are aimed at developing a new generation of tools for measuring state variables and rates in the environment. Most projects are in early stages of their research where the tools are not yet available, but have excellent plans for products that will provide broad-accessibility to environmental measurements. A number of new instruments are being designed for unattended measurement for long-term observations, and many project include efforts for web-based information dissemination of results as the instruments come on line. Some projects also have plans for interactive museum/visitor center displays.

The one-year planning activity coordinated by David Crosley at SRI International (CTS 0120000) is an excellent example of shared research and facilities that addresses the goal of accessibility. The project "Teaming to Enable University Research on Hazardous Emissions Through New Instrumentation and Student Internships" aims to develop an instrument for analyzing combustion byproduct emissions that are environmental hazards. The goal of the collaboration among research groups at the Georgia Institute of Technology, Louisiana State University, the Environmental Protection Agency, and SRI International was to develop a jet-REMPI (resonantly enhanced multiphoton ionization) instrument for analyzing combustion byproduct emissions that are environmental hazards such as dioxins, furans, and polycyclic aromatic hydrocarbons (PAHs). Current methods of analysis are very time consuming, requiring up to a month for a single analysis. Adaptation of this fast technique (time scale of seconds) will remove a major impediment to progress in several areas of environmental chemistry.

James Ammerman at Rutgers University and his colleagues are developing a continuous underway system for measurement of marine microbial enzyme activities (OCE 0216154). This new technology will provide a high-resolution picture of microbial metabolic rates that is unattainable with present technologies. The development of this system is an important step toward a capability to remotely assess the metabolism of marine microbes at unattended ocean observatories.

An example of a tool that promises to be broadly-accessible is being developed by Paul Flikkema at Northern Arizona University and his colleagues (EF 0308498). This project was also cited under item B1 as an example of integrating Native American students into cutting-edge technological research. This group is using wireless network technology similar to that used in cell phones to monitor ecosystem processes. The sensors are designed to save on costs, reduce labor intensity, and will have longevity with less maintenance than traditional monitoring equipment.

Through a collaboration between the Monterey Bay Aquarium Research Institute and the Elkhorn Slough National Estuarine Research Reserve (ESNERR), Kenneth Johnson and his colleagues (OCE 0308070) are developing a Land/Ocean Biogeochemical Observatory (LOBO) for nutrient and carbon cycling. A part of their activities involve the development of chemical sensors for unattended measurements in the environment. An interactive exhibit in the ESNERR Visitor Center is also planned. The general public, other scientists and students can view real time data from the LOBO; they also will have the opportunity to see how data are collected, relayed and interpreted. This project also includes plans for a curriculum model for high school teacher training.

4.4 B.4 OUTCOME GOAL for ORGANIZATIONAL EXCELLENCE: Providing "an agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices."

Comments:

The heart of any excellent organization is excellent personnel. The Biocomplexity in the Environment program is fortunate to be implemented by a corps of dedicated, hard-working, and innovative people who are able to work together effectively as a team. Whatever issues arise below, this corps manages to deliver to the community it serves. This organization tries to be both as agile and as responsive as the Congressional budget cycle will permit.

Congress has questioned NSF's ability to manage interdisciplinary research. We view the structure as having developed as a response to both scientific and management challenges – the scientific, educational, and international activities that BE represents involve the entire breadth of Foundation activities with seven directorates and two offices involved in the competitions. The individuals managing BE activities on behalf of the Foundation were distributed in diverse directorates, divisions and programs. Program review and program management in BE thus needed to involve diverse and numerous NSF personnel and required them to perform in novel ways. BE required consultation and buy-in on a massive scale.

Our overall finding is that the resultant management structure while not excellent is good enough. It delivers high quality science with broad impact. NSF personnel have learned to use the current structure to accomplish what needs to be done, even though it may be balky. Were the COV reviewing a management structure that needed to persist for another 10 years, it would recommend a wholesale replacement. Given that the BE competition may last only a few more years, the effort required to replace the present management structure for BE might not be recouped. Crosscutting programs that involve multiple directorates within the NSF, however, are very likely to continue and very possibly grow in scope. **A thorough analysis of how best to manage crosscutting programs in general is clearly required.** This analysis should consider issues such as staffing requirements, fund management, decision-making processes, time use efficiency, preparation and review of program announcements, and outcomes assessment.

Despite this general conclusion, there are several issues that would benefit from immediate attention:

1. Team members all have "a day job", the disciplinary Programs that they manage, in addition to their Team managerial roles. The resultant amount of effort that is required is massive, and may jeopardize the ability of the Team members to provide high-quality management and leadership to both their Team and their Program. **The COV challenges BE Program Management to address this issue proactively and aggressively**. Some suggestions: There would be immediate payoffs in streamlining management activities so that team members' time is conserved. There is a need for more Program Assistant support in home programs. Some of the budget issues (addressed below) mean that team members cannot effectively manage their time. Now that it has been established that team members can act effectively as advocates for their Team program as a whole rather than just representing their disciplinary efforts, there could be increased delegation of activity to team members without such extensive consultation.

2. A tremendous amount of effort is diverted to organizing the finances of the program (and thus away from ensuring that the finances are allocated to the best/broadest impact science). Projects supported under the BE initiative are funded through multiple mechanisms that range from programmatic decisions at the division level to crosscutting decisions involving multiple directorates. Streamlining of the financial management structure of crosscutting programs like BE would simplify the concerns of program directors ultimately making and managing awards from such crosscutting competitions.

3. There seems to exist some tension between team leaders and team members involved in the various sub-themes within the BE competition and the WG-ERE. This friction may relate to the management structure that has been established to direct environmental research and education within the NSF, but it appears to be an issue that needs to be addressed. The success of this crosscutting initiative and similar initiatives of the future will be highly dependent on the confidence and commitment of program directors running the competitions. A clear and frank dialog between program directors involved with running these competitions and the WG-ERE should be encouraged to address this underlying tension that seems to have developed during the BE competition.

5.0 COV TEMPLATE PART C: OTHER TOPICS

5.1 C.1 Please comment on any program areas in need of improvement or gaps (if any) within program areas.

The BE Competition, particularly CNH, is to be commended for its efforts to incorporate the social sciences and natural sciences. The program's emphasis on interactions and impacts of human factors in the global ecological system has ensured the early inclusion of social sciences in this new area of research from the beginning. The COV believes this may contribute to more mutual partnerships between social and natural sciences than is commonly seen. That said, the COV notes that the degree of integration of both social sciences and education in BE could be strengthened. That is, while the program solicitations reflect the desire and need for strong social science and educational components, they have not yet emerged prominently in the portfolio. Hence, there are a few concerns in this area for future consideration:

- The COV found that in many instances social sciences were interpreted as "societal impacts" in proposals. It should be made clearer to the research communities unfamiliar with social sciences that social scientists conduct, as well as communicate, research. BE–CNH might help to improve the appreciation and interaction of social and natural sciences by offering social science summer institutes for natural scientists who want to learn social science techniques and methods. A reciprocal institute might be offered by natural scientists for social scientists.
- The COV believes that the definition of social sciences has been somewhat narrow to date, focusing primarily on quantitative social sciences. In the words of one staff representative, the objective has been to "include quantitative goals and complex modeling in order to demonstrate the 'seriousness' of the program." The COV suggests that the program's view of relevant social sciences be expanded to include rigorous qualitative as well as quantitative methods. In addition to developing ever more complex models of natural and human coupling, research should increasingly attend to more sophisticated surveys and analyses of human (inter)actions, processes, values, and decisions that can elucidate questions of biocomplexity, but that cannot be adequately captured in quantitative models.
- While we are beginning to see applications of network methods to the field of biocomplexity (for example, S. Borgatti taught an NSF-sponsored Biocomplexity Incubation workshop on the Application on Network Theory to Biocomplexity in Mach 2001), they seemingly are not yet well-represented in projects based on our limited and selective reading of jackets and reports. Network thinking (see, for example, Barabâsi, A. L. 2002. *Linked : the new science of networks*. Perseus Publications, Cambridge, Mass., or visit the International Network of Social Network Analysts http://www.sfu.ca/~insna/)) seems to be a rising tide that strongly resonates with BE. The new science of networks asks, in essence, what are the common rules that govern the structure and function of networks wherever they appear in natural, engineered, and human (e.g., social and economic) systems, and what are the general implications of structural variation of networks for their function? Network thinking could be particularly important for BE because it represents what could be a common language for physical, biological, and social scientists and educators, and thereby facilitate interdisciplinary activity. For this reason, BE should consider how best to bring these developments to the attention of the PI community (e.g., workshops, support of presentations at meetings), and implement these.

The COV also voices its support for investing the time necessary to build the interdisciplinary teams to make the BE competitions successful in the long-term. There are languages and cultures of the various types of science and engineering embodied in the BE competitions that must be communicated across disciplines. This will take time, and the NSF should commit to continued building of these interdisciplinary communities fostered by the BE competitions into the future.

C.1.a Please comment if applicable on the extent and nature of collaboration and coordination with related programs.

The BE program includes seven directorates and two offices within the NSF. Few if any programs have achieved this level of collaboration and coordination at the Foundation. There are growing pains associated with implementing such a wide-ranging and ambitious program, but the pluses outweigh the minuses. Collaborations to date have been solely within the NSF, but collaborations with other agencies might develop in the future around BE themes.

C.1.b Please comment if applicable on the performance of this program compared to other cross-divisional programs.

The program under review is novel in that it is a cross-directorate program, rather than a cross-divisional one. The present COV is the first to review such a cross-directorate program; we have no quantitative benchmark for comparison. It is apparent that NSF personnel from all directorates and offices were very actively involved in the direction of this program.

5.2 C.2 Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

The formal BE competition focused on five thematic areas. In addition to NSF-wide Merit Criterion (#1) and Broader Impacts Criterion (#2), the BE solicitations included three additional specific criteria (quantitative approaches, integration of research and education, and global perspective). Despite the newness of the program, the COVs overall assessment is that the program appears to be successful in meeting program-specific goals. The COV's evaluation of the program's response to Criteria 1 and 2, including education, are discussed in answers to questions in template section B. Fewer specific results on the efficacy of quantitative approaches are in hand, but preliminary results from the BE investigator workshops suggest that the program will be successful in meeting goals. Statistics on the number of proposals with an explicit global perspective were not available. A discussion on the success in including social sciences can be found in C1, above.

5.3 C.3 Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

1. Staffing levels (preferably through release time and appropriate use of program assistants) need to be increased for these complex multi-directorate solicitations.

2. It is important to guarantee that sufficient resources in the directorates be devoted to support site visits and other related activities.

3. Some assessment of incubator/planning awards is needed – what are the outcomes? For example, do they lead to more successful applications for full proposals? Do they lead to new collaborations?

4. The internal flow of funds and participant data should be streamlined; see B4.

5. The review process for highly interdisciplinary programs involves another dimension of complexity than most disciplinary programs. In particular, ensuring the quality of interdisciplinary activities involves reviewing both the quality of those disciplinary contributions as well as the integrative aspects of the project or program. The review process should explicitly address both dimensions of such projects.

6. A modified format is needed for these multi-PI, multi-institution proposals. It is almost impossible for a COV member to quickly determine what investigators and institutions are involved, what role each plays, and the dollars each requests. If multi-/interdisciplinarity is to be a criteria of BE awards, mechanisms for more easily identifying the multi-/interdisciplinarity nature of proposals should be introduced into the proposal review process. Such a mechanism should allow reviewers to (a) easily account for the number and the nature of the different disciplines represented in the proposal, and (b) quickly identify the scientific bearing that each discipline has on the proposed problem(s) and the strategies that the project proposes for actively engaging each discipline in the problem(s).

5.4 C.4 Please provide comments on any other issues the COV feels are relevant.

NSF has made a commendable effort to improving diversity in the research portfolios by paying attention to minority participation in the review process and in the evaluation and awarding of proposals. Efforts to date, however, do not appear to have increased the number of minority participants significantly. In order to improve these efforts, the review panel selection process should be expanded. A specific effort to include panel members from minority-serving institutions should be made. Senior researchers from these institutions will become knowledgeable about the NSF budget and review process, and will be better equipped to advise their students about how to submit a successful proposal. The impact of having panelists from minority-serving institutions should be that both the pool of proposals from minority researchers will increase, and proposals of high quality would be generated in the future from minority researchers.

More detailed justification in Form 7s is needed as to why a highly rated proposal is not funded and why a “gray” area proposal is funded. The justification for not funding a highly rated proposal is typically “insufficient funds.” However, there are most likely other factors involved that are not discussed in many of the Form 7s. It would be helpful to the COV and the overall reputation of the BE program if the factors involved in making a final fund or decline recommendation for competitive proposals was clearly captured in the Form 7s. One mechanism to provide a better overview is to have a summary for each solicitation, with an expanded statement as to why final decisions were made; these overviews could be placed in each jacket.

The low success rate for funding for a number of the competitions raises concern that the community may become discouraged and choose not to compete in the future.

The time scale for growing and maturing a community is greater than five years (life time of the priority area); the balance between soliciting new themes and providing some consistent support for maturing teams and communities needs a serious review by NSF management.

The formal BE competition has selected five thematic areas that evolved and became more focused over the program's lifetime. Given the funding constraints of the BE program, it was necessary to restrict the number of topics; the Working Group on Environmental Research and Education has put

considerable thinking into the selection of these topics. As themes evolved in the early years, the solicitations changed from year to year, to the consternation of the review community. The 90 days from posting of solicitation to submission deadline is insufficient for complex interdisciplinary proposals if the guidelines (topics and dollar limits) vary from year to year.

Other topics are being covered with BE funds that are not part of the formal BE competition and hence were not reviewed by the COV. We have no basis for comment on those projects; the committee would have benefited from an overview of the "unfenced" activities of BE to truly understand the entire scope of BE.

5.5 C.5 NSF would appreciate your comments on how to improve the COV review process, format and report template.

This is the first of NSF's major new initiative or priority areas to undergo a COV review. The COV review process is a rapid-paced evaluation of a program within the NSF. A COV focused upon a crosscutting program like BE that involves seven directorates and two offices within the NSF adds additional challenges not present in a typical program review. The diversity of science and engineering that requires evaluation is truly daunting and stretches the expertise of any COV panel.

We offer the following suggestions:

1. A written description of the review process, reflecting and explaining differences in the mechanics of the review among different sub-themes, would have helped the COV come up to speed more rapidly. Some programs use only panel reviews while others use a combination of panel and mail or external reviews. An overview and rationale for when one process versus the other is justified should be clearly presented.

2. A separate COV template for crosscutting programs should be developed to better accommodate the special additional needs of highly interdisciplinary programs such as BE. Many of the questions on the current COV have limited relevance to interdisciplinary initiatives and other questions that focus on the challenges of crosscutting competitions are missing.

3. The difficulty in compiling overall statistical data describing the program is understandably challenging in that data must be compiled from across many different program units. Nonetheless, this is an important issue to be addressed to make sure the COV groups have or can easily compile data to inform their deliberations. For example, the lack of basic statistics on "awards to new investigators," geographical distribution of PIs," and "institutional types" hampered the COV's ability to come to substantive conclusions about the performance of the program in these areas in this first BE review.

4. Time spent with the team leaders was particularly valuable in understanding challenges in organizing and running a major crosscutting competition. This interaction between the COV and NSF program personnel should be given more time and possibly involve smaller subgroups involving specific sub-themes.

5. More time with the jackets would have been useful.

6. Proposals to BE, or to any highly interdisciplinary program should include a list of PI and co-PIs along with their disciplines. Clear documentation of the research team that reflects the inter-disciplinary, international, and inter-institutional nature of the proposed effort would be valuable. Perhaps a specialized cover sheet template for interdisciplinary proposals should be developed. The COV found it difficult to review the jackets and had to "dig" to figure out the entire cast of players in each proposed effort.

7. An overview COV concerning the BE is a useful first step in evaluating the overall competition. COVs directed at each of the sub-themes after five year of competitions might be a useful follow-up to this general COV directed at the entire portfolio of BE competitions.